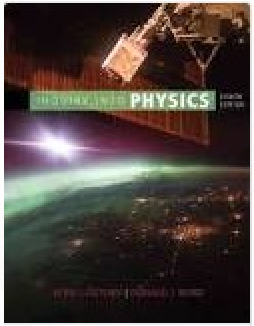
Energy – Work
conservation of energy

The physics of everyday phenomena: a conceptual introduction to physics
by W. Thomas Griffith, McGraw-Hill

Inquiry into Physics
Vern J. Ostdiek, Donald J. Born



Physics / Edition 8
by John D. Cutnell, Kenneth W. Johnson, Cutnell

Energy

- **Energy** is defined as the measure of a system's ability to do work. That is to apply a force over a distance. This idea of energy was unknown to Newton. If an object has energy, damage can be done to another Object by going into it = transfer of energy

  - We use the symbol E to represent energy.
  - Energy has the same units as work:
    - Joule for SI, ft·lb for English

UNITS again

- The units of energy:
  - Metric
    - SI: joule ($J = N \cdot m$),
    - erg ($= 10^{-7}$ J = 0.0000001),
    - calorie (cal = 4.186 J),
    - 1 food Cal = 1000 cal=4,186 J
    - kilowatt-hour (kWh = 0.278 J).
  - English:
    - foot-pound ($ft \cdot lb$),
    - British thermal unit (Btu).

FORMS OF ENERGY

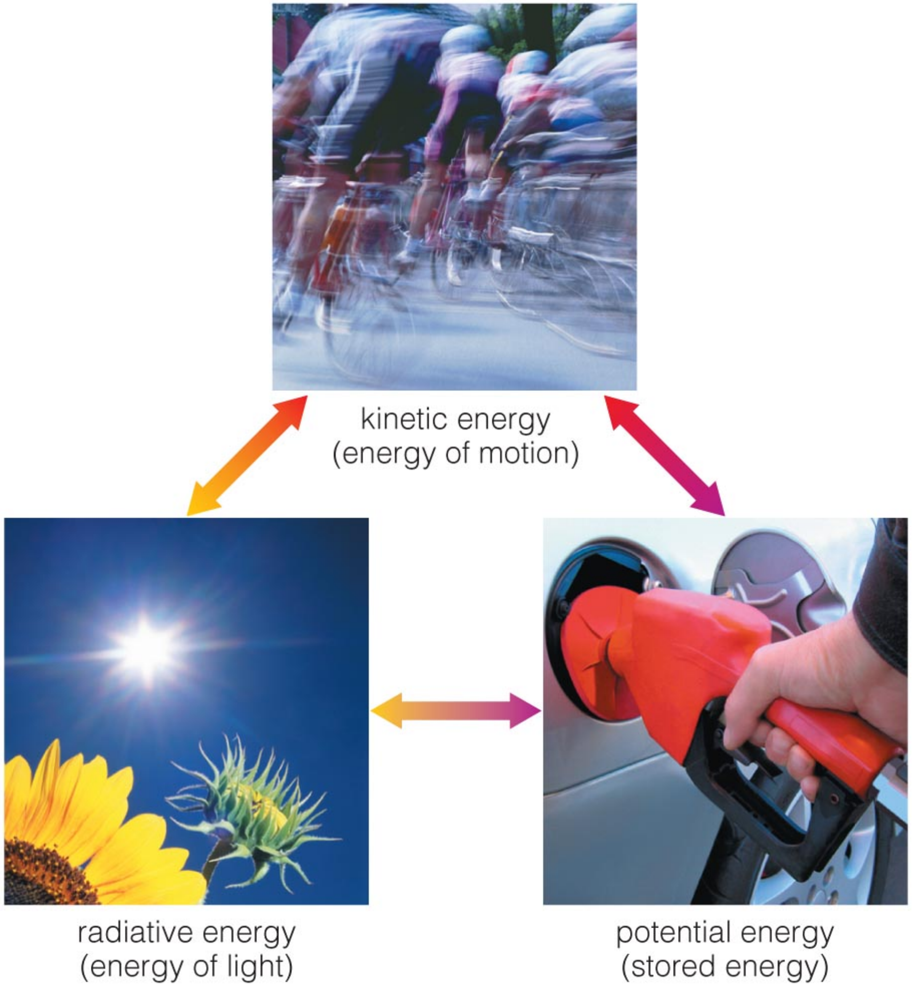
Kinetic (motion)

Radiative (light)

Potential (stored)

Energy can change type, but cannot be created or destroyed.

Energy can be converted from one form to another.



KINETIC ENERGY

- There are various types of energy.
  - **Kinetic energy** is the energy associated with an object's motion.
    - We use the symbol KE. $KE = \frac{1}{2} m V^2$
    - **Change in kinetic energy : $\Delta KE = 0.5\ m\ (Vf^2 - Vi^2)$**

Note that the kinetic energy depends on the speed squared

So if you double your speed on the highway , damage during a potential Crash is multiply by 4 !!! This was not known to Newton. Leibniz (co-founder of calculus) got the idea after an experiment was done with dropping balls in clay . Double the speed the balls have, Multiply the marks in the clay by 4 !!

Example:

1) A 50kg child runs at a speed of 5m/s and stop.
What is the change in kinetic energy ? HINT:

First find the Final kinetic energy
Then the initial kinetic energy then :

Change= FINAL – INITIAL

2) A person has a mass of 45kg and is moving with a velocity of 10m/s.
Find the person's kinetic energy?

The person's velocity becomes 5m/s. What is the kinetic energy ?

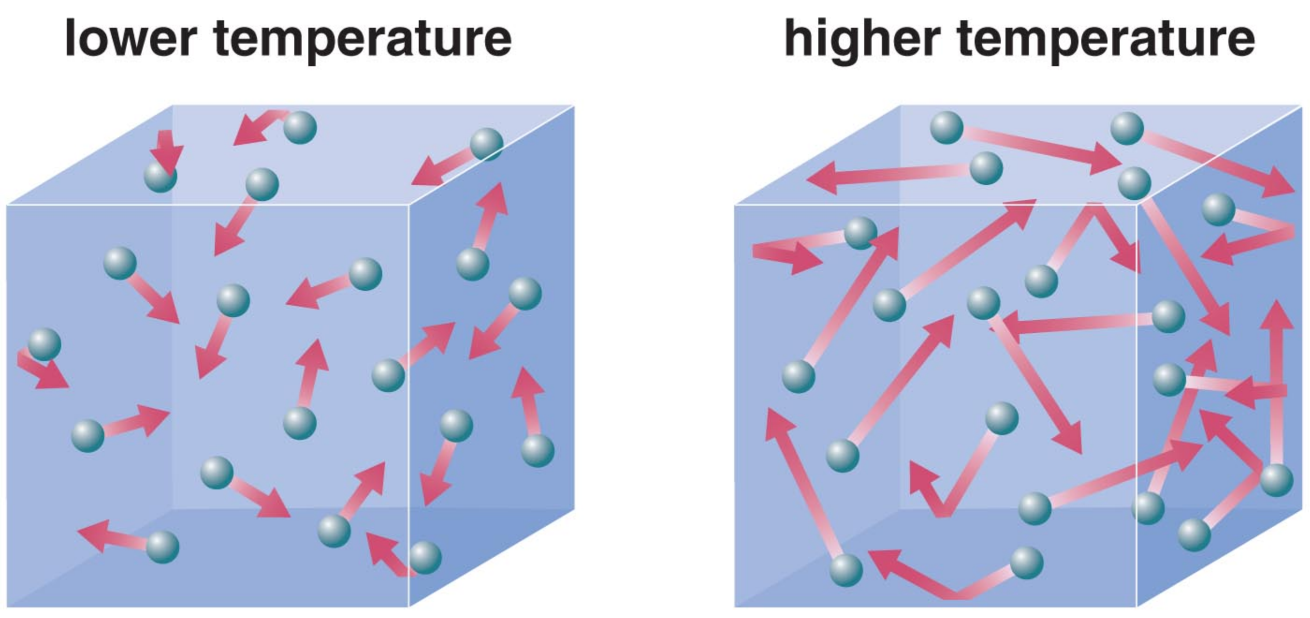
What is the ratio of the speeds ?
What is the ratio of the kinetic energy ?
Conclusion ?

Thermal Energy:

the collective kinetic energy of many particles (for example, in a rock, in air, in water)

Thermal energy is related to temperature but it is NOT the same.

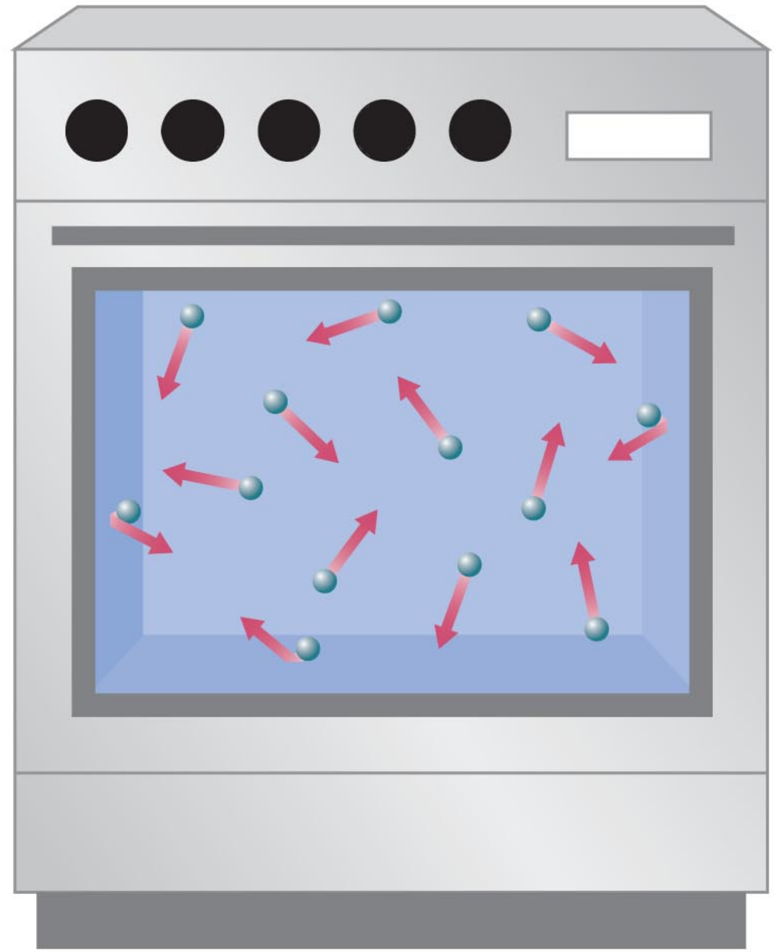
Temperature is the *average* kinetic energy of the many particles in a substance.



Thermal energy is a measure of the total kinetic energy of all the particles in a substance. It therefore depends on both *temperature* AND *density.*

Example:

212°F



400°F

POTENTIAL ENERGY IS STORED ENERGY. It's a binding energy. Or negative energy. Potential energy is energy associated with the system's position or orientation. We use the symbol PE.

- CHEMICAL POTENTIAL ENERGY (plants, coal, oil, cookies ..)
The energy is in the bonds between atoms. These forces Are like compressed springs. The can expand suddenly. The forces are electromagnetic forces.

-NUCLEAR ENERGY = energy stores in the nuclei. $E = mc^2$
Energy stored in the bonds between nucleons.

- GRAVITATIONAL POTENTIAL ENERGY (a book above the groun
Gravity bonds us to the Earth, bonds the stars in galaxies and galaxies in cluster. On Earth we compute the change in potential energy and we take PE = 0 at ground level.
$\Delta PE = m\, g\, \Delta h$ (g=10m/s/s)

$$\Delta PE = \frac{1}{2} K (\Delta x)^2$$

- ELASTIC POTENTIAL ENERGY
(a compressed or stretched spring..)

Example

A 3-kg brick is lifted to a height of 0.5 meters above a table that is 1.0-m tall. Find the gravitational potential energy relative to the table and the floor.

$\Delta PE = m\ g\ x \Delta height$

Potential energy is relative to a reference level

You can take PE = 0 where ever it is convenient

For computations. PE=0 at ground level.

The PE is meaningless without specifying the reference level.

1) A 3600kg boat is moving with a velocity of 2.4m/s. A much smaller 100kg jet ski has the same amount of kinetic energy. What is the velocity of the jet ski?

Try first without the hints !

2) A7.00kg bowling ball travels a distance of 5.00m in 4.00s. How much kinetic energy does it have in J?
(hint: compute the speed first)

3) How much work does it take to make a 77.7kg wagon speed up from 0.8m/s to 3.3m/s?
(hint Work, by definition, is equal to a change in kinetic energy)

4) How much work does a tugboat need to do in order to move a barge from rest to a velocity of 0.550m/s?
The mass of the barge is 879,000kg. The mass of the tugboat is insignificant.
(hint: work is the change in KE)

5) How much work is done by gravity when a 7.64kg boulder falls to the ground from the top of a 33.4m tall cliff? (hint: compute the PE that will turn to KE)

6) A 8kg box is 0.5m above table 1 m high. What is the PE of the box relative to table and ground ?

7) You have a spring-loaded air rifle. When it is loaded, the spring is compressed 0.3m and has a spring constant of K =150N/m. In joules, how must elastic potential energy is stored in the spring? Hint: elastic PE= 0.5 K $(X)^2$ X is the distance compressed or stressed.

8) How much negative work in J is needed to slow a 588kg barge from a velocity of 1.1m/s to 0.4m/s? Hint: convert g to kg. Work is the change in KE.

9) An AR-15 rifle shoots a 4.10g bullet straight up with a velocity of 905m/s. It returns to the Earth a little while later with a velocity of 111m/s.How much negative work was done on the bullet by drag forces?
Hint: work is the change in KE

10) How much work is required to compress a spring, k=33.3N/m, from its equilibrium point at x=0.0mto x=5.0m? (work = change in energy).

11) How much work is required to compress a spring (k=33.3N/m) from t x=5.0m to x=7.00m?

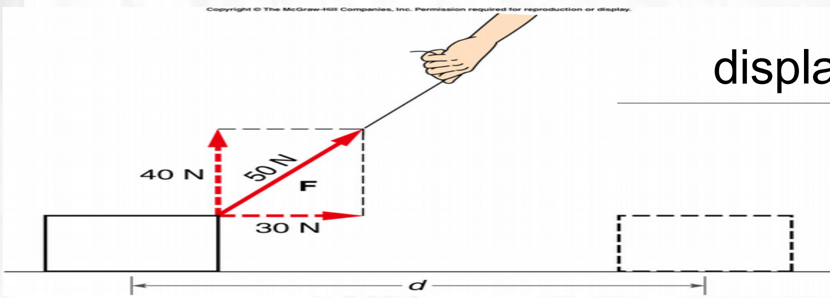
12)A large household air conditioner may consume 15.0kW of power. What is the cost in dollars of operating this air conditioner 3.00h per day for 30.0d if the cost of electricity is \$0.110 per kWh?
Hint energy(kWh) = power (kW) x time(hours)

In PHYSICS”

WORK MEASURES The AMOUNT of ENERGY of motion Transferred FROM one SYSTEM to another. Work on a system is done by a force only it changes the energy of the system.

Work = F// x distance

Work in joules, distance in meter, force F in newtons



displacement

F//=30N distance = 10m

Work = 30 x 10

Example: Y**ou push a box with a force Of 100N and if the box is moving by 4m Then the energy transferred from your Body (energy stored in fat) to the box (energy of motion)**

= ________ x __________ = ________ J

Work, cont'd

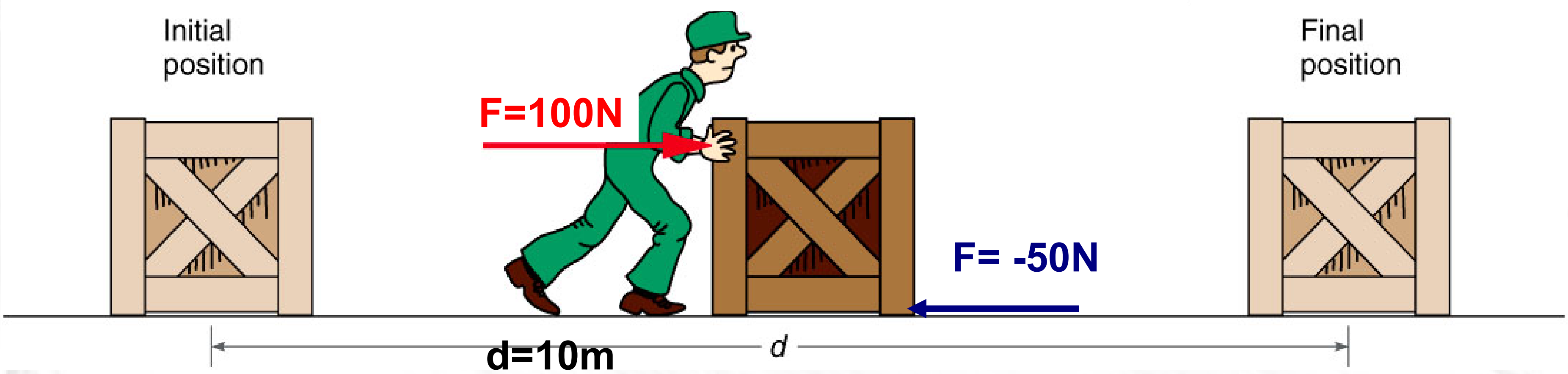
- Recall that force is a vector.
  - Involves magnitude and direction.
- Work is just that part of the force in the direction of the displacement.
  - Work is not a vector — it's a scalar.
- But the sign of the work does depend on the relative directions.

If work <0 energy is removed from the system

- **If work >0 energy is added to the system also: work is done on a system only if the speed changes.**

- If the force and distance are in the same direction, the force does *positive work*.

If the force and distance are in the opposite direction, the force does *negative work*.



Work by the guy = ____ J **work by the friction = ____ J**

NET Work = ____J **CHANGE IN ENERGY = ____________ J**

A suitcase has a mass of 10kg.

Find its weight in newtons

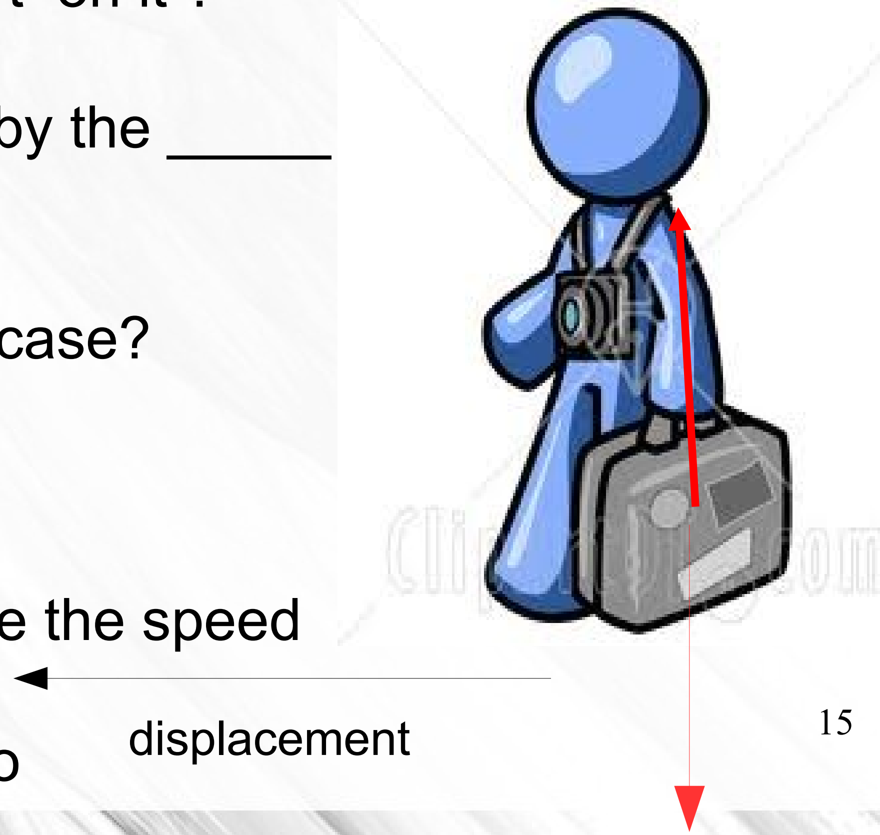
If you want to carry the suitcase , what is the Upward force you need to exert on it ?

The upward force is balanced by the _____ of the suitcase.

Are you doing work on the suitcase?

Is gravity doing work ?

No because they don’t increase the speed In the forward direction.
The forces are perpendicular to Displacement. Wdone = 0

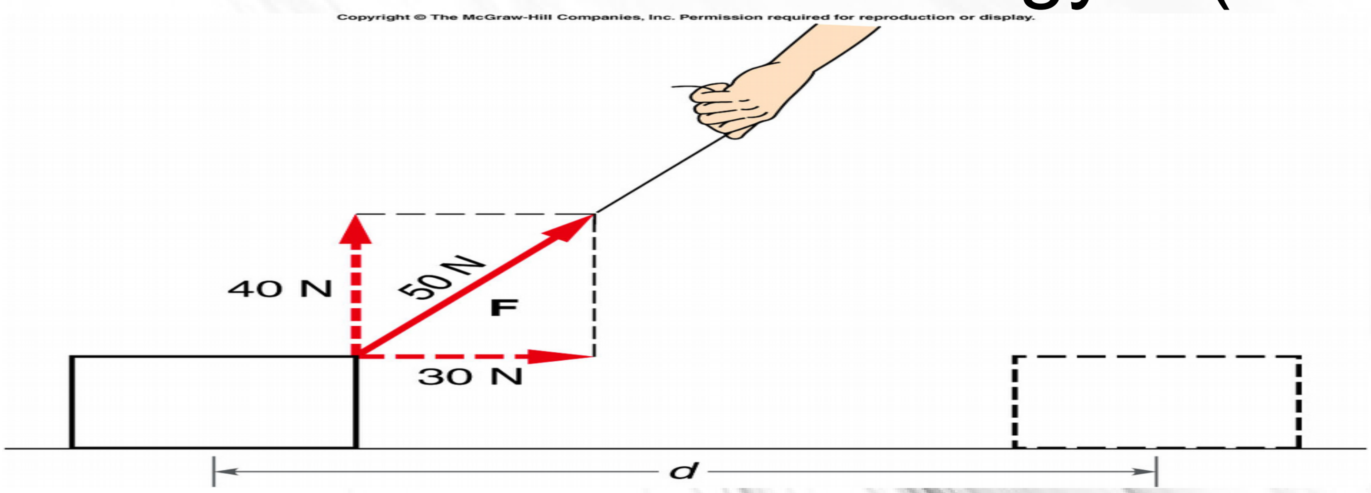


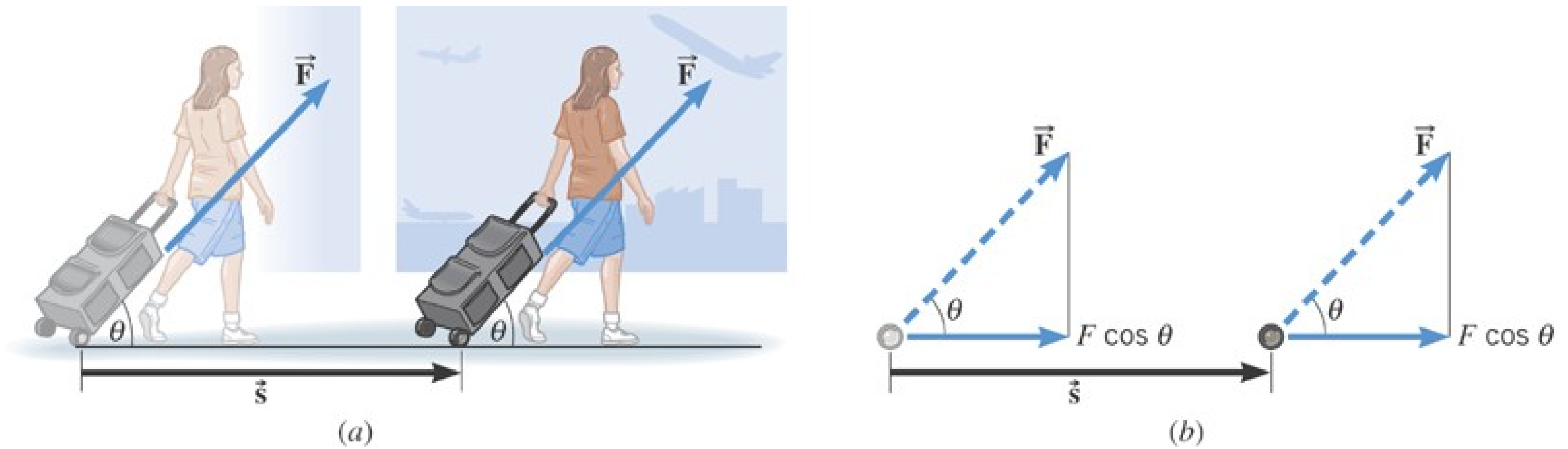
If the force is not in the direction of the direction, the force does *no work*.

Bellow the pulling force for has 2 components, which component can increase the energy of the box (10kg) ?

So which component does work ?

Find the increase of energy ? (d=10m)





Example 1 Pulling a Suitcase-on-Wheels

Find the work done if the force is 45.0-N, the angle is 50.0 degrees, and the displacement is 75.0 m.

Work-Kinetic Energy Theorem

When work is done by a net force on an object and the only change in the object is its speed, the work done is equal to the change in the object's kinetic energy

- Speed will increase if work is positive
- Speed will decrease if work is negative

Example:

You are pushing a box with a force of 100N
But a 50N frictional force opposes the motion.

1) Find the work done by each force

2)Find the net work (distance is 5m)

3) Find the increase in kinetic energy

4) If the initial speed of the box is 0(starts from rest) and if the Box is 50 kg , find the final speed.
KE=0.5 m v^2

Example

Because of friction, a constant force of 100 newtons is needed to slide a box across a room. If the box moves 3 meters, how much work must be done?

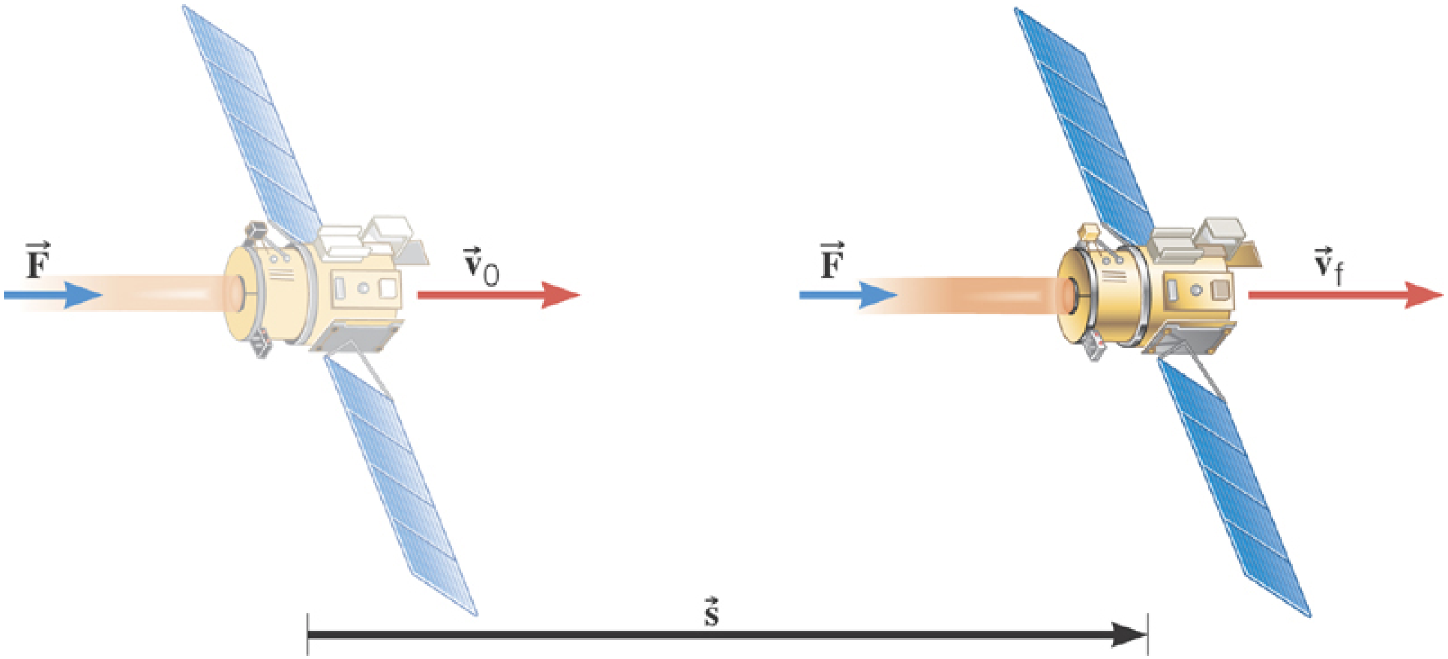
(that is how much work you are doing on the box).

If the friction is – 100N, what is the work done by the Friction force ?

What is the total net force ? the net work ?
The change in kinetic energy ?

Example 4 Deep Space 1

The mass of the space probe is 474-kg and its initial velocity is 275 m/s. If the 0.056 N force acts on the probe through a displacement of 2.42×10^{9}m, what is its final speed?

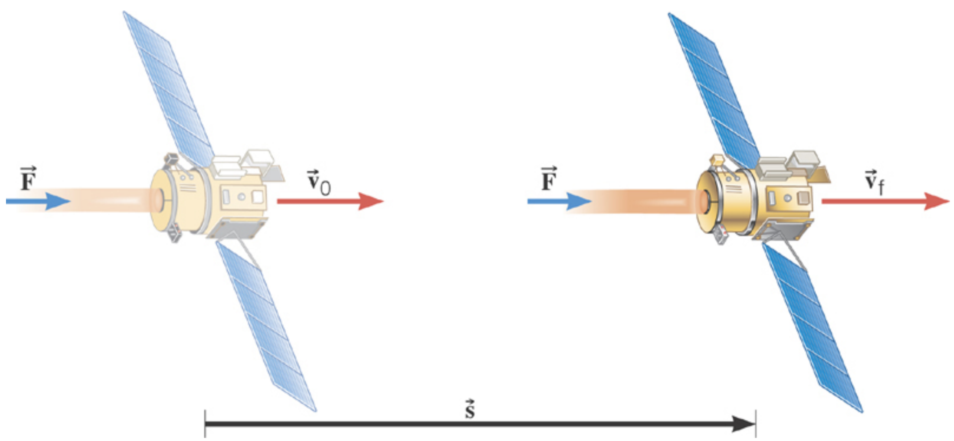


$$\left[\left(\sum F\right)\cos\theta\right]s = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_o^2$$

$$\left(5.60\times10^{-2}\,\mathrm{N}\right)\cos 0^\circ\left(2.42\times10^{9}\,\mathrm{m}\right) = \tfrac{1}{2}\left(474\,\mathrm{kg}\right)v_f^2 - \tfrac{1}{2}\left(474\,\mathrm{kg}\right)\left(275\,\mathrm{m/s}\right)^2$$

$$\downarrow$$

$$v_f = 805\,\mathrm{m/s}$$



1) In the 1950s, an experimental train that had a mass of 2.50 10^4 kg was powered
Across a level track by a jet engine that produced a thrust of 5 10^5 N for
A distance of 509m .
A) Find the work done on the train
B) Find the change in kinetic energy
C) Find the final speed of the train if there were no friction.(initial speed is 0)

2) A 2,000 kg has a speed of 12m/s. The car hits a tree. The tree does not move, and the car comes to rest.
A) Find the change in kinetic energy
B) Find the amount of work done in pushing in the front of the car
C) Find the size of the force that pushed into the front of the car by 50cm.

3) A constant lift of 410N is applied upward to a stone that weighs 32N. The Upward force is applied through 2m.
A) What is the net work done on the stone ?
B) What is the change in kinetic energy?
C) if the stone is 5 meters above the ground,
what is its potential energy?
4) The force applied to the wagon is 100N @ 60
The wagon is pulled over a distance of 10m

A) what is the work done.
B) if there is a frictional force of 40N, what is the network?

Conservation of energy

- The **Law of Conservation of Energy:** energy cannot be created or destroyed.
  - The total energy of an isolated system is constant.
    - The energy of the Universe is constant.
- Energy can only be transformed from one form to another.

Conservation of energy

- If the energy of an isolated system is constant, the energy before an event must the same as the energy after an event.

$$\text{total energy before} = \text{total energy after}$$

Conservation of energy

- To deal with energy conservation, we need the total energy:

$$\text{total energy:}$$

$$E = KE + PE = \text{constant}$$

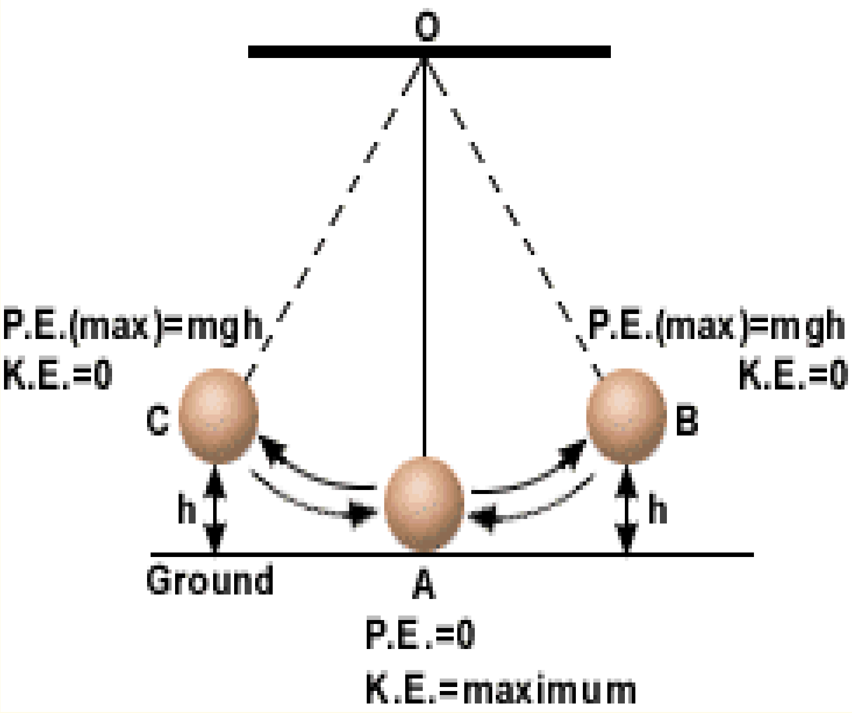
Simulations with exploration of physical sciences:

1) KE and PE of a falling ball
2) pendulum. Note that you need to decide of a level for which PE =0
3) spring and mass. Pel = 0.5 K x^2
4) frosty
5) jump

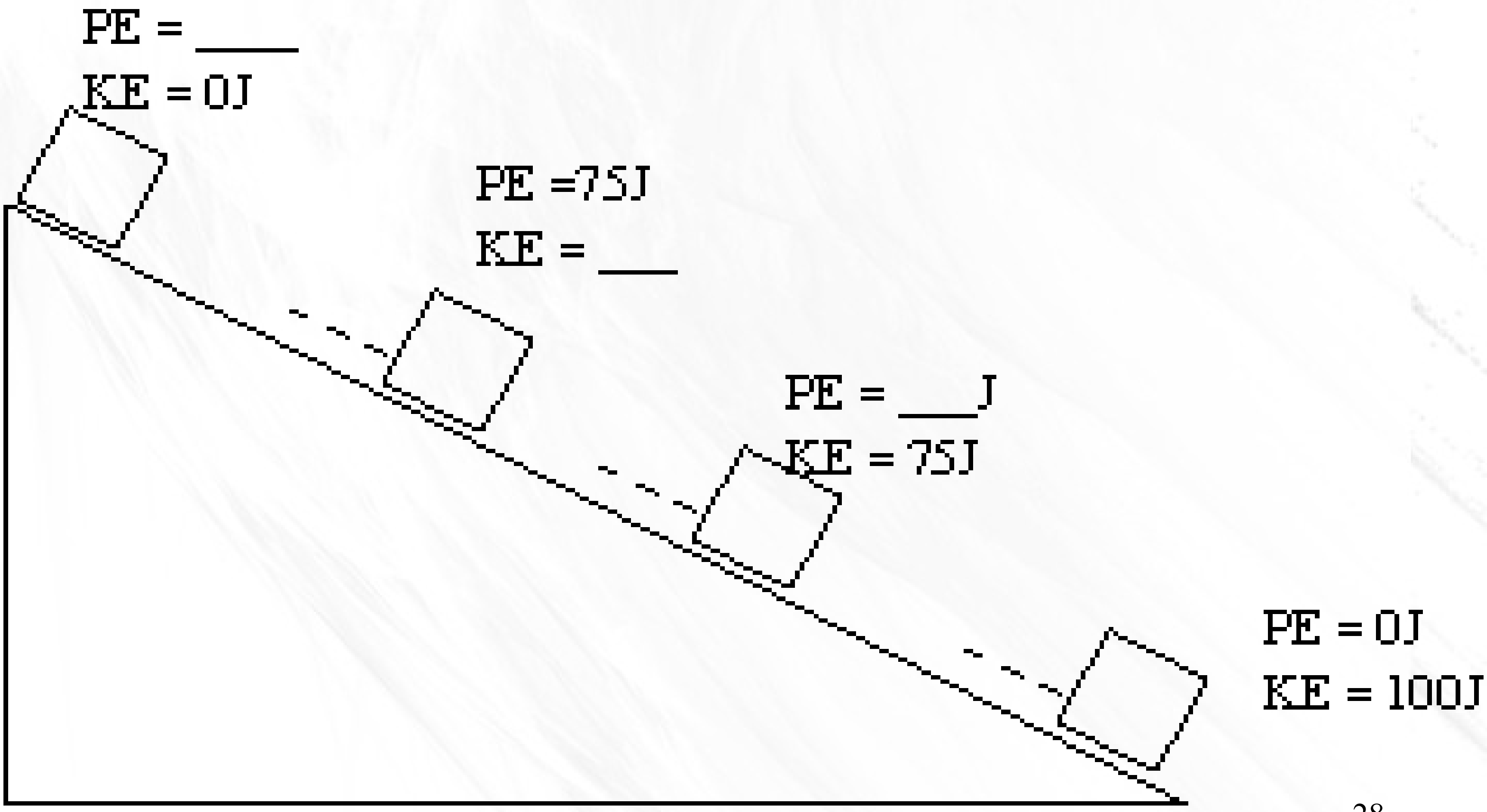
Source: http://www.physicscurriculum.com/

Conservation of energy

- We can understand a roller-coaster or a pendulum by as an example of energy conservation.



COMPLETE. A block slides on a frictionless plane:



PE = 15 000J

KE = 0

PE = 11,250J

KE = __________

PE = 7,500J

KE = _________

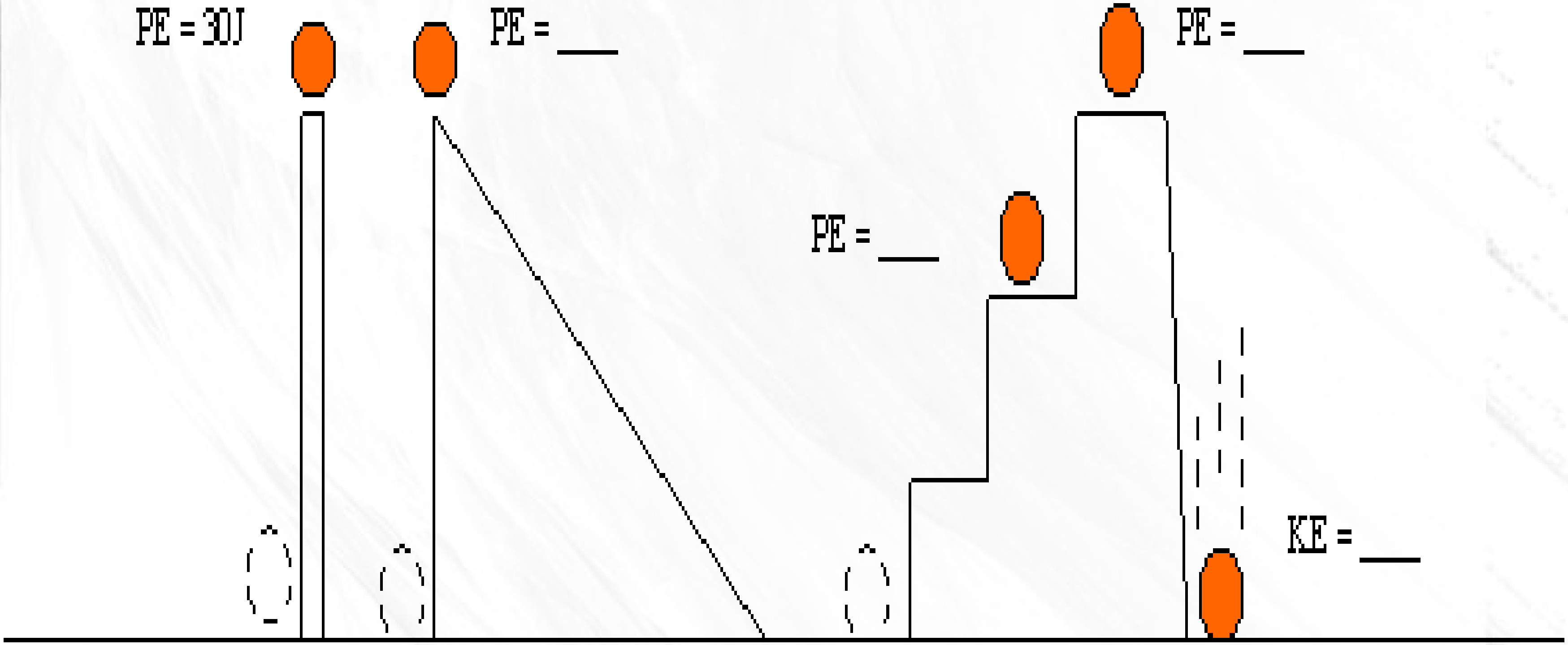
PE = 3,750 J

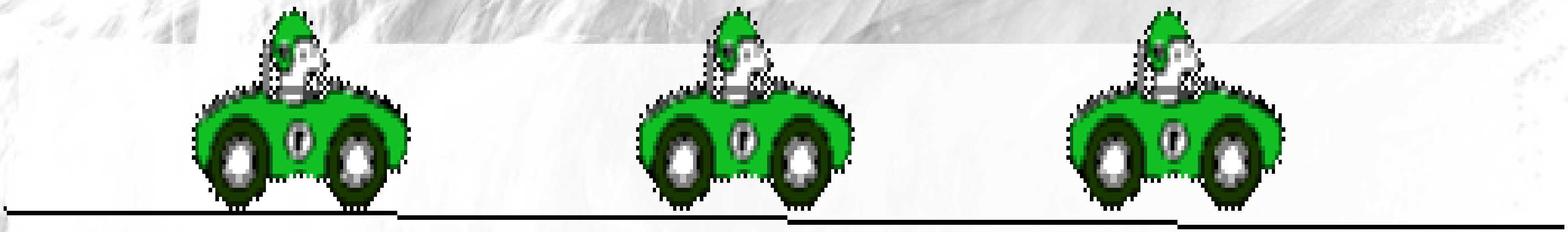
KE = _________

PE = 0 J

KE =

To get the ball at the top, you can roll it up the ramp or you can lift it. Will the change in energy be the same ? Why ?





V= 30km/h

KE = 10^6J

V= 60km/h

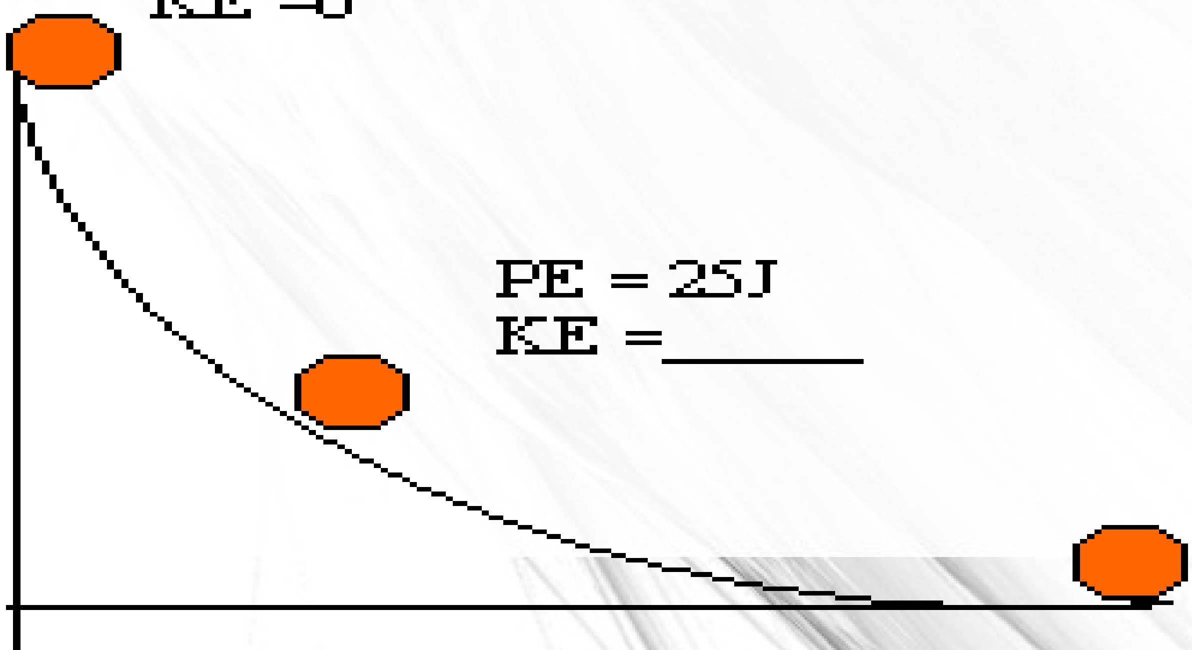
KE = ___

V= 90km/h

KE = ___

PE = ________

KE =0



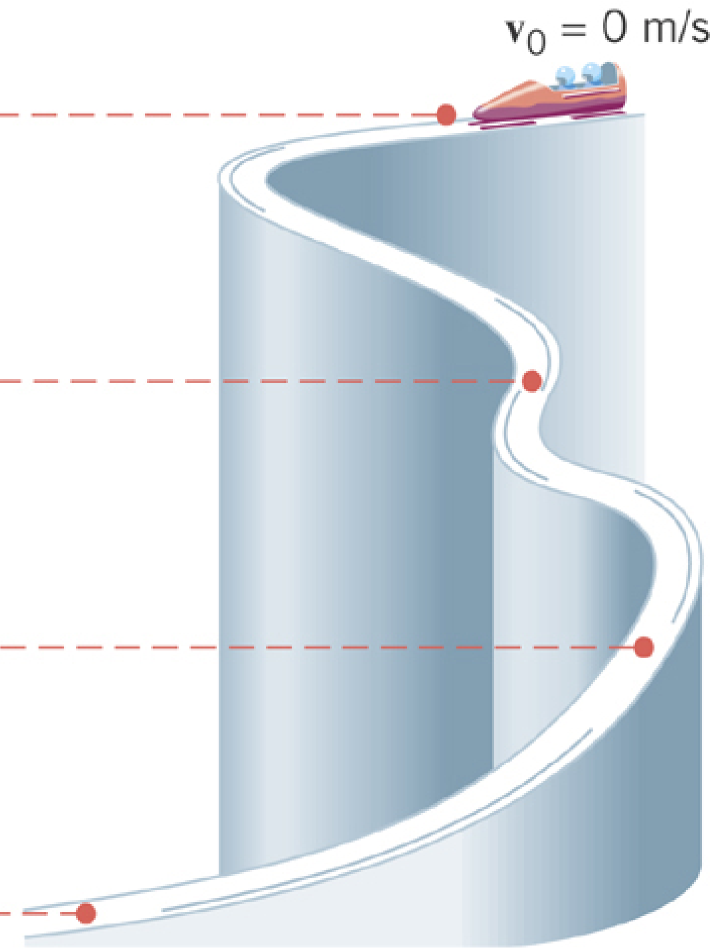
PE = 25J

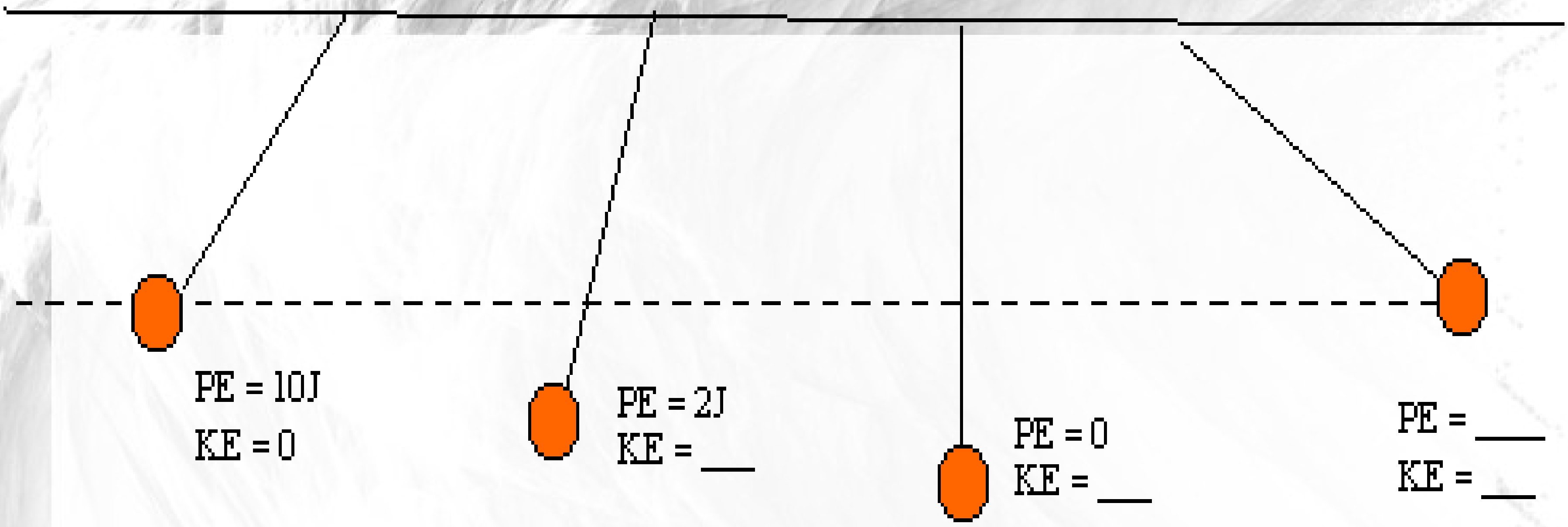
KE =_______

PE = 0J

KE =50J

KE	PE	E = KE + PE
0 J	600 000 J	600 000 J
200 000 J	400 000 J	600 000 J
400 000 J	200 000 J	600 000 J
600 000 J	0 J	600 000 J





Starting from rest the cart glides friction less to point P, which is 4.5m below the top of the hill. How fast is it going at P ?

P

Example

In 2003, a man went over Horseshoe Falls, part of Niagara Falls, and survived. The height of the falls is about 50 meters. Estimate the speed of the man when he hit the water at the bottom of the falls.

Video Wlater Lewin

http://www.youtube.com/watch?v=mhIOylZMg6Q

http://www.youtube.com/watch?v=8vu2cKu5pjg

DISCUSSION:

The speed does not depend on the man's mass.

If you tried this, you'd hit the bottom with the same speed.

This is obviously ideal:

- We do not consider air resistance. That would convert some of his KE into heat and sound. The real speed would be slower.

Example

I toss a 0.06-kg tennis ball straight up. When it leaves my hand, it has a speed of 20 m/s. Find how high the ball rises.

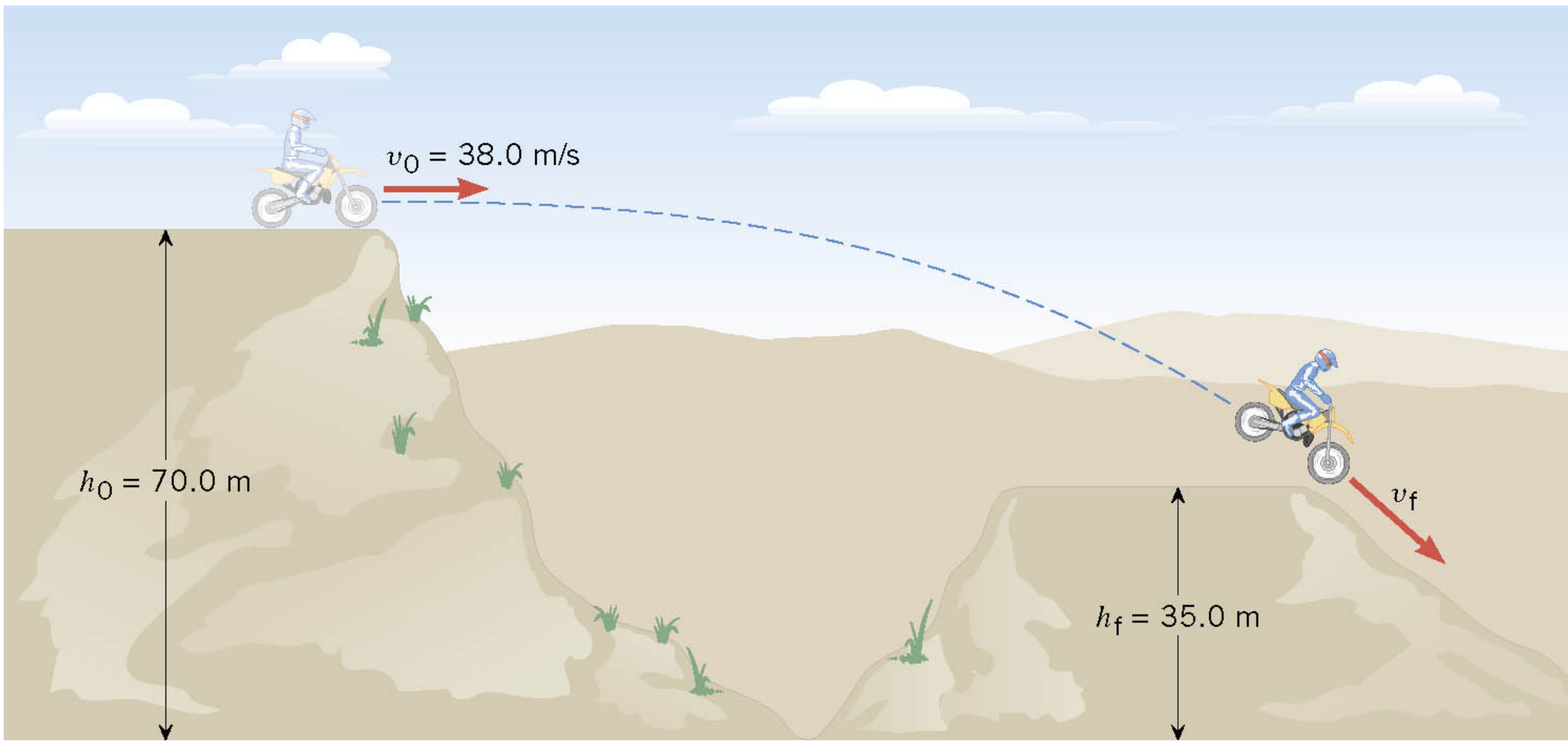
Note : you can use the kinematics equation for free-Fall

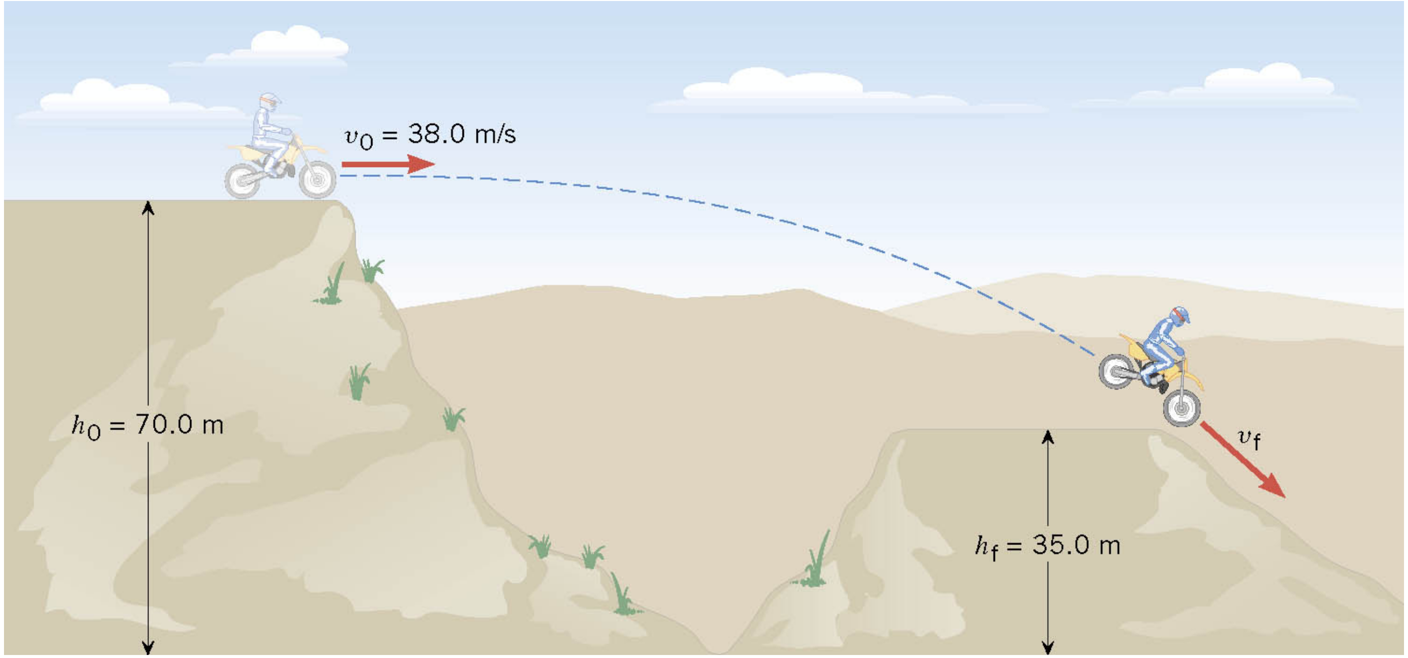
DISCUSSION:

Again, since we neglect air resistance the height would be the same if I tossed a tennis ball, bowling ball or brick.

Example 8 A Daredevil Motorcyclist

A motorcyclist is trying to leap across the canyon by driving horizontally off a cliff 38.0 m/s. Ignoring air resistance, find the speed with which the cycle strikes the ground on the other side.

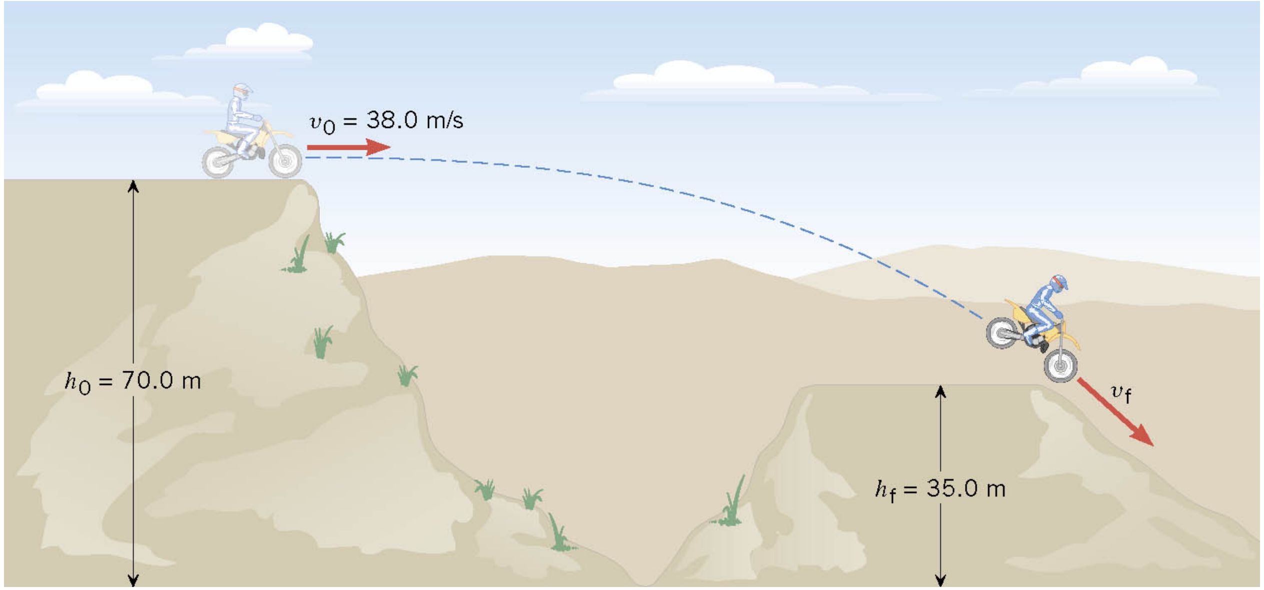




$$E_f = E_o$$

$$mgh_f + \tfrac{1}{2}mv_f^2 = mgh_o + \tfrac{1}{2}mv_o^2$$

$$gh_f + \tfrac{1}{2}v_f^2 = gh_o + \tfrac{1}{2}v_o^2$$



$$gh_f + \tfrac{1}{2}v_f^2 = gh_o + \tfrac{1}{2}v_o^2$$

$$v_f = \sqrt{2g\left(h_o - h_f\right) + v_o^2}$$

$$v_f = \sqrt{2\left(9.8\,\mathrm{m/s^2}\right)\left(35.0\,\mathrm{m}\right) + \left(38.0\,\mathrm{m/s}\right)^2} = 46.2\,\mathrm{m/s}$$

DEFINITION OF AVERAGE POWER

Average power is the rate at which work is done, and it is obtained by dividing the work by the time required to perform the work.

$$\overline{P} = \frac{\text{Work}}{\text{Time}} = \frac{W}{t}$$

$$\text{joule/s} = \text{watt (W)}$$

$$\overline{P} = \frac{\text{Change in energy}}{\text{Time}}$$

$$1 \text{ horsepower} = 550 \text{ foot} \cdot \text{pounds/second} = 745.7 \text{ watts}$$

Change in energy = force x distance if the force is constant.
So power = force x distance/time = force x average speed

$$\overline{P} = F\overline{v}$$

6.7 Power

Table 6.4 Human Metabolic Rates[a]

Activity	Rate (watts)
Running (15 km/h)	1340 W
Skiing	1050 W
Biking	530 W
Walking (5 km/h)	280 W
Sleeping	77 W

[a]For a young 70-kg male.

We are like a 100W light bulb !!
So we spend 100 J/ second.
Compute how much energy do we spend in 1 day.
Convert to food calories. 4,184 joules = 1 Cal

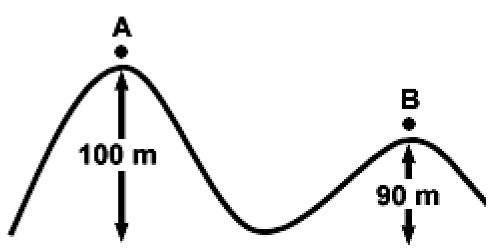
1) Which has the greater kinetic energy - a 1-ton car moving at 30 m/s, a half-ton car moving at 60 m/s?

2) A 20 N ball and a 40 N ball are dropped at the same time from a height of 10 meters. Air resistance is negligible.
A)Compute the speed of impact for each object.
B)change of momentum of each object and impulse at impact

3) Jim exerts a force of 500 N against a 100-kg desk that does not move.
Virgil exerts a force of 400 N against a 60-kg desk that moves 2 m in the direction of the push.
Mik exerts a force of 200 N against a 50-kg desk that moves 4 m in the direction of the push.
The most work is done by ?

4) Suppose you climb the stairs of a ten-story building, about 30 m high, and your mass is 60 kg. The gravitational potential energy you gain is about

5) A skie speed at B ?



http://www.sparknotes.com/physics/workenergypower/conservationofenergy/problems_1.html

ESCAPE VELOCITY

Fire bullets up and they will come back down ! (some people don't realize that).

You need 7 miles per second to escape Earth gravity. (11km/s).
Interestingly, an object from infinity falls on earth with the same speed.

To find the speed : gravitation energy = kinetic energy.
Solve for the speed.

$$\frac{1}{2}mv_i^2 - \frac{GM_E m}{R_E} = \frac{1}{2}m0^2 - \frac{GM_E m}{\infty}$$

$$\frac{1}{2}mv_i^2 - \frac{GM_E m}{R_E} = 0 - 0$$

$$\frac{1}{2}mv_i^2 - \frac{GM_E m}{R_E} = 0$$

$$V_e = \sqrt{\frac{2GM}{R}}$$

$$= \sqrt{\frac{2 \times 6.6726 \times 10^{-11} \times 5.9742 \times 10^{24}}{6378100}}$$

$$= \sqrt{\frac{2 \times 6.6726 \times 5.9742 \times 10^{24-11}}{6378100}}$$

$$= \sqrt{\frac{79.73 \times 10^{13}}{6378100}}$$

$$= \sqrt{125005879.5} \quad = 11180.6 \text{ m/s}$$

http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::800::600::/sites/dl/free/0072482621/78778/Escape_Nav.swf::Escape%20Velocity%20Interactive